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EFFECTS OF EXTERNAL ENVIRONMENTS ON THE SHORT BEAM SHEAR STRENGTH OF FILAMENT WOUND GRAPHITE/EPOXY

(Center Director's Discretionary Fund Final Report)

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Materials and Processes Laboratory
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16. ABSTRACT

Filament wound graphite/epoxy samples were immersed in seawater, deionized water, and toluene at room temperature and 80°C for 5, 15, and 43 days, and in methanol at room temperature for 15 and 43 days. The percent weight gains and short beam shear strengths were determined after environmental exposure. Samples immersed in deionized water and seawater had higher percent weight gains than those immersed in toluene at room temperature and 80°C. The percent weight gains for samples immersed in methanol at room temperature were comparable to those of deionized water and seawater immersed samples. A comparison of percent decreases in short beam shear strengths could not be made due to a large scatter in data. This may indicate defects in samples due to machining or variations in material properties due to processing.

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INTRODUCTION

Structural components fabricated from fiber reinforced polymers are finding wide applications in automobiles, commercial and military aircraft, and space systems because of their high strength, high stiffness, and low weight. In order to take advantage of these excellent properties, the effects of external environments during usage on the mechanical properties of composite materials need to be understood. This is especially true when material failure due to exposure to external environments can result in loss of life, injury, or high financial losses.

The effects of temperature, moisture, and various organic liquids on the mechanical properties of epoxy resin reinforced with graphite [1-7] have been studied. Degradation of mechanical properties most likely occurs due to debonding of the fiber and matrix and/or cracking of the matrix.

Short beam shear and flexural strength measurements have been used to examine the effect of environments on the mechanical properties of composite materials. For example, Rege and Lakkad [8] examined the effect of salt water and distilled water on carbon and graphite reinforced epoxy. Degradation in salt water was found to be more severe for the composite systems that were studied. Joshi [9] measured the short beam shear strengths of unidirectional carbon/epoxy samples immersed in boiling water. The shear strengths were found to decrease with an increase in the amount of absorbed moisture.

The purpose of this paper is to report preliminary results of a study directed at determining the effects of seawater, deionized water, methanol, and toluene on the short beam shear strengths of filament wound graphite/epoxy systems used in the Space Shuttle.

EXPERIMENTAL

Materials

The dry seawater salt mixture was purchased from Lake Product Co., St. Louis, Missouri. The composition of this mixture is shown in Table 1. The seawater was prepared by dissolving 41.95 g of salt mixture in 1000 ml of water as specified by the supplier.

The SRB-Filament Wound Case (FWC) segments were fabricated using an epoxy system composed of a mixture of Bisphenol A epoxy and 1,4 butanediol epoxy. The curing agent was a blend of methylene dianiline and m-phenylene diamine. The reinforcement was graphite fibers manufactured by Hercules and designated as A S4W-12K.

Short Beam Shear Strength

The interlaminar shear strength was measured in accordance with ASTM-D 2344-76 short beam shear procedure. An Instron machine with a crosshead speed of 0.05 in./min was used. The size of the transverse specimens was 1.5 x 0.25 x 0.25 in.

Machining of Short Beam Shear Specimens

Large pieces of specimens were cut from actual segments of the SRB-FWC and machined to dimensions of 1.5 x 0.25 x 0.25 in. This was carried out by cutting the large pieces of segment into 1.5-in. vertical strips. Each of these were then cut in the horizontal direction to give pieces having a length of 1.5 in. and width of 0.25 in. Samples with a thickness of 0.25 in. were prepared by cutting the necessary amount from the two remaining uncut faces. The machining process is illustrated in Figure 1.

Environmental Testing

Samples machined to dimensions of 1.5 x 0.25 x 0.25 in. as described were immersed in deionized water, seawater, or toluene at room temperature and 80°C for 5, 15, and 43 days. In addition, samples were immersed in methanol at room temperature for the specified lengths of time. Control samples were also prepared and heated for the required amounts of time in a desicator placed in an oven. After environmental exposure the samples were subjected to percent weight gain determination and short beam shear strength measurements.

RESULTS AND DISCUSSION

Percent Weight Gains in the Liquid Environments

The percent weight gains for filament wound graphite/epoxy samples immersed in deionized water, seawater, and toluene at room temperature and 80°C for 5, 15, and 43 days are summarized in Tables 2 through 4. The highest values were obtained for deionized water and seawater which had percent weight gain values ranging from 0.58 to 1.7 and 0.48 to 1.7, respectively. In comparison, the percent weight gain values ranged from 0.28 to 0.59 for toluene. Based on these results, deionized water and seawater are expected to degrade mechanical properties more than toluene.

The percent weight gains of samples immersed in methanol at room temperature are presented in Table 5. The percent weight gain values are 1.3 and 2.7 for 15 days and 43 days, respectively. This preliminary data indicate that methanol might have a significant effect on the degradation of mechanical properties since its percent weight gains are comparable to those of seawater and deionized water. This phenomenon will be further investigated in future projects.

Analysis of Environmental Effects on the Short Beam Shear Strength

The effects on the short beam shear strengths of immersion in seawater, deionized water and toluene at room temperature and 80°C for 5, 15, and 43 days are summarized in Tables 2 through 4. Moreover, the effects of immersion in methanol

for 15 and 43 days at room temperature are presented in Table 5. The standard deviation values, which range from 179 to 615 for the controls and immersed samples, are too high and variable for determining the quantitative effects of the liquids on the short beam shear strengths. This trend in standard deviation values might be due to machining defects or variations in the properties of the composite samples. These prospective causes will be thoroughly examined in future programs.

CONCLUSION

Graphite/epoxy samples machined from large segments, which were fabricated by the same process that will be used to make the SRB FWC, were immersed in deionized water, seawater, and toluene at room temperature and 80°C for 5, 15, and 43 days, and in methanol at room temperature for 15 and 43 days. The percent weight gains for samples immersed in toluene was less than those of samples immersed in deionized water and seawater. The percent weight gains for methanol exposed samples were comparable to those of seawater and deionized water immersed samples which suggest that the effects of alcohols and other polar liquid on the mechanical properties of this composite system should be further investigated.

A comparison of the percent decreases in short beam shear strengths was not attempted due to the wide data scatter and the small number of samples tested. The scatter in data might indicate the presence of defects in samples resulting from machining operations or there might have been variations in the properties of the filament wound segment. This investigation will continue using this study as a basis.

REFERENCES

1. Browning, C. E., Husman, G. E., and Whitney, J. M.: Moisture Effects in Epoxy Matrix Composites. In Composite Materials: Testing and Design (Fourth Conference), ASTM STP 617, American Society for Testing, 1976, pp. 481-496.

2. Springer, G. S., Ed.: Environmental Effects on Composite Materials. Technomic Publishing Co., Inc., Westport, CT, 1981.

3. Browning, C. E.: Effects of Moisture on the Properties of High Performance Structural Resins and Composites. Proc. 28th Ann. Tech. Conf. Reinf. Plast./ Com. Inst., SPI, 1973, Sec. 15A.

4. Hertz, J.: Investigation Into the High-Temperature Strength Degradation of Fiber-Reinforced Composites During Ambient Aging. Tech. Rept. GDCA-D 6B71-00403, Contract No. NAS8-27435, 1972.

5. Shen, D., and Springer, G. S.: J. Composite Materials, Vol. 11, 1977, p. 2.

6. Gillat, O., and Broutman, L. J.: Effects of External Stress on Moisture Diffusion and Degradation in a Graphite-Reinforced Epoxy Laminate. In Advanced Composite Materials-Environmental Effects, ASTM STP 658, J. R. Vinson, Ed., American Society for Testing and Materials, 1978, pp. 61-83.

7. Browning, C. E.: Polym. Eng. Sci., Vol. 18, No. 1, 1978, p. 16.

8. Rege, S. K. and Lakkad, S. C.: Fibre Science and Technology, Vol. 19, 1983, pp. 317-321.

9. Joshi, O. K.: Composites, Vol. 14, No. 3, 1983, pp. 196-200.

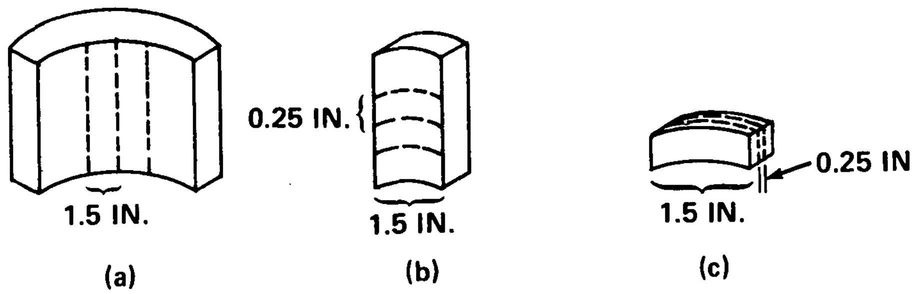

Figure 1. Machining of specimens for short beam shear strength measurements. Cutting of 1.5 in. dimension (a), 0.25 in. width (b), and 0.25 in. thickness (c).

TABLE 1. COMPOSITION OF SEAWATER SALT MIXTURE ACCORDING TO MANUFACTURER

Component	Percent Composition
$NaCl$	59.490
$MgCl_2$	26.460
Na_2SO_4	9.750
$CaCl_2$	2.765
KCl	1.645
$NaHCO_2$	0.447
KBr	0.238
H_3BO_3	0.071
$SrCl_2$	0.095
NaF	0.007

TABLE 2. SHORT BEAM SHEAR STRENGTH AFTER 5 DAYS OF ENVIRONMENTAL EXPOSURE

Environment	Property Measured	Room Temperature	80°C	Number of Samples Tested: Room Temperature	Number of Samples Tested: 80°C
Deionized Water	Short Beam Shear Strength (psi)	5266	5200		
	Standard Deviation	345	510	4	4
	Percent Weight Gain	0.58	0.80		
Seawater	Short Beam Shear Strength (psi)	5671	4723		
	Standard Deviation	394	426	4	4
	Percent Weight Gain	0.48	0.58		
Toluene	Short Beam Shear Strength (psi)	5043	4472		
	Standard Deviation	544	382	5	5
	Percent Weight Gain	0.28	0.32		
Control	Short Beam Shear Strength (psi)	5463	5192		
	Standard Deviation	352	481	4	4
	Percent Weight Gain	0.21	0		

TABLE 3. SHORT BEAM SHEAR STRENGTH AFTER 15 DAYS OF ENVIRONMENTAL EXPOSURE

Environment	Property Measured	Room Temperature	80°C	Number of Samples Tested: Room Temperature	Number of Samples Tested: 80°C
Deionized Water	Short Beam Shear Strength (psi)	5083	5222		
	Standard Deviation	403	488	5	4
	Percent Weight Gain	1.1	1.0		
Seawater	Short Beam Shear Strength (psi)	5146	4868		
	Standard Deviation	348	477	4	4
	Percent Weight Gain	1.2	1.0		
Toluene	Short Beam Shear Strength (psi)	5628	4119		
	Standard Deviation	484	309	4	5
	Percent Weight Gain	0.47	0.50		
Control	Short Beam Shear Strength (psi)	5330	5248		
	Standard Deviation	186	519	4	5
	Percent Weight Gain	0.24	0		

TABLE 4. SHORT BEAM SHEAR STRENGTH AFTER 43 DAYS OF ENVIRONMENTAL EXPOSURE

				Number of Samples Tested	
Environment	Property Measured	Room Temperature	80°C	Room Temperature	80°C
Deionized Water	Short Beam Shear Strength (psi)	5038	4929		
	Standard Deviation	482	179	5	4
	Percent Weight Gain	1.5	1.7		
Seawater	Short Beam Shear Strength (psi)	6283	5236		
	Standard Deviation	368	518	5	5
	Percent Weight Gain	1.43	1.7		
Toluene	Short Beam Shear Strength (psi)	5167	5310		
	Standard Deviation	387	300	4	4
	Percent Weight Gain	0.59	0.52		
Control	Short Beam Shear Strength (psi)	5103	5103		
	Standard Deviation	315	615	5	5
	Percent Weight Gain	0.30	0		

TABLE 5. SHORT BEAM SHEAR STRENGTH AFTER IMMERSION IN METHANOL AT ROOM TEMPERATURE

Environment	Property Measured	15 Days	43 Days
Methanol	Short Beam Shear Strength (psi)	5210	4863
	Standard Deviation	446	215
	Percent Weight Gain	1.30	2.7
	Number of Samples Tested	5	3
Control	Short Beam Shear Strength (psi)	5330	5103
	Standard Deviation	186	315
	Percent Weight Gain	0.24	0.30
	Number of Samples Tested	4	5

APPROVAL

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The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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